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(54) Real-time fault detection in an instrument landing system

Echtzeit-Fehlererkennung bei einem Instrumentenlandesystem

Détection des pannes en temps réel dans un système d'atterrissage aux instruments

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Description

Background

[0001] An instrument landing system (ILS) is a ground-based system that provides precision guidance to an aircraft approaching and landing on a runway. The ILS uses Very High Frequency (VHF) and Ultra High Frequency (UHF) guidance signals to enable a safe landing during conditions such as low ceilings or reduced visibility due to fog, rain, or blowing snow. The ILS includes ground-based transmitters that transmit the guidance signals to a receiver on-board the aircraft. The guidance signals produce ILS navigation outputs that are used by the flight control system to bring the aircraft to a safe landing on the runway.

[0002] Undetected malfunction of ILS receiver signal processing may result in mission failure that could have catastrophic consequences. Thus, conventional systems have built-in fault detection capabilities. Some on-board ILS receivers detect possible malfunctions using two or more identical receiver paths, coupled to a shared antenna, and tuned to the same radio channel containing the ILS guidance signal broadcasted by the ILS ground station. Each ILS receiver path performs identical, or near-identical, computations on the same input signal to produce the ILS radio guidance data. A malfunction is detected when ILS receiver paths produce different guidance data. The drawback of this approach is the cost associated with employing additional full receiver paths and the reduction in receiver sensitivity associated with splitting the antenna output into multiple inputs for each of the receivers which cuts down on the maximum range at which the guidance signals can be detected.

[0003] Another approach favored by the large airplane manufacturers is to feed a single on-board receiver from an antenna to demodulate the desired guidance signals and then digitize the demodulated signal in two parallel digital processing chains to produce the radio guidance data. The processors compare their guidance data to detect any malfunction in the digital processing chain in real-time. To detect malfunctions in the RF down conversion/demodulation, signals whose malfunction may cause erroneous data are also monitored in real-time. In addition a test signal is injected into the RF receiver input during all phases of flight during which the landing guidance signal is not to be received, and signal processors monitor the test signal to detect any malfunction in the RF chain up until the landing final phase of flight is started. The drawback of this approach is that any malfunctions in RF components that cannot be monitored during final approach and landing can result in a loss of guidance.

[0004] A method which provides the capability to detect any receiver malfunction in real-time without added parts count and without degrading the receiver sensitivity/maximum detection range would be highly desirable.

[0005] US3820115A discloses a radio receiver for navigational or guidance of aircraft, including a channel of

conventional processing circuits for processing the received radio signals to activate a course indicator, circuitry for superimposing rider signals on the received radio signals near the input end of the channel, apparatus for comparing the rider signals after processing through the channel with their original form, and an alarm indicator for indicating selected differences between the compared signals.

[0006] US3750176A discloses an integrity monitor for an aircraft Instrument Landing System receiver in which malfunctions are detected by comparing the outputs of identical guidance signal channels. Tracer signals are injected to prevent total guidance channel failure from being mistaken as a valid condition. Automatic means adjust comparison tolerances to permit a greater difference in guidance channel outputs without alarm when the aircraft is in the clearance area and to reduce the permissible difference when the aircraft is on-course.

Summary

[0007] The present invention provides a receiver for an instrument landing system, according to claim 1 of the appended claims.

[0008] The invention further provides a method for real-time fault detection in a receiver of an instrument landing system, according to claim 7 of the appended claims.

[0009] An electronic system with real-time fault detection is provided. In one embodiment, the system includes analog circuitry, having a first input coupled to receive an input signal and a second input coupled to receive a test signal. The test signal is at an edge of a selected band that contains the input signal. The test signal is used to identify faults in the electronic system during operation of the electronic system. The electronic system further includes an analog to digital (A/D) converter coupled to an output of the analog circuitry. The A/D converter generates digitized spectrum. Digital circuitry is coupled to the output of the A/D converter. The digital circuitry processes the input signal from the band to provide an output for the system and processes the test signal to detect faults in the analog circuitry, the digital circuitry and the A/D converter.

Brief Description of the Drawings

[0010] Understanding that the drawings depict only exemplary embodiments and are not therefore to be considered limiting in scope, the exemplary embodiments will be described with additional specificity and detail through the use of the accompanying drawings, in which:

Figure 1 is a block diagram of an on-board receiver in an Instrument Landing System (ILS) that includes a wide-band front end and a bank of digital down-converters according to one embodiment of the present invention.

Figure 2 is a flow chart of one embodiment of a meth-

od for detecting faults in an on-board receiver of an ILS according to one embodiment of the present invention.

Figure 3 is a perspective diagram of an ILS with real-time detection of faults in an on-board receiver according to one embodiment of the present invention.

Figure 4 is a block diagram of another embodiment of an electronic system according to the teachings of the present invention.

Detailed Description

[0011] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific illustrative embodiments. However, it is to be understood that other embodiments may be utilized and that logical, mechanical, and electrical changes may be made. Furthermore, the method presented in the drawing figures and the specification is not to be construed as limiting the order in which the individual steps may be performed. The following detailed description is, therefore, not to be taken in a limiting sense.

[0012] Embodiments of the present invention provide an ILS with real-time fault detection in an on-board receiver. The on-board receiver uses one or more wideband front end circuits that are tuned to the navigation bands containing guidance signals for the ILS. The term guidance signal refers to the localizer and glide slope signals or their equivalent in an automated landing system such as ILS. The on-board receiver also generates and injects test signals at the edge of each of one or more bands at the input to the respective wideband front end during the flight, including during the phase in which the guidance signals are received. The on-board receiver processes the guidance signals input to the wideband front ends using a combination of digital and analog circuitry. The on-board receiver detects faults in the digital circuitry by comparing redundant output calculations based on the guidance signals. The on-board receiver detects faults in the analog circuitry by comparing the test signals output from the digital circuitry with expected values.

[0013] Figure 1 is a block diagram of an on-board receiver 100 in an ILS that includes wideband front ends 102 and 104 and a bank of digital down-converters 106 according to one embodiment of the present invention. Receiver 100 includes both analog circuitry (including mixed signal circuitry) and digital circuitry. Receiver 100 is designed to enable real-time detection of faults in both the analog circuitry and the digital circuitry that makes up receiver 100. In one embodiment, the analog circuitry includes the wideband front ends 102 and 104 as well as analog-to-digital (A/D) converters 116 and 118. The digital circuitry includes the bank of digital down-converters 106, the main processor 120 and the monitor processor 122.

[0014] Receiver 100 receives guidance signals from

ground-based transmitters of the ILS and processes the signals to provide input to a flight control system on-board an aircraft (see Fig. 3). Receiver 100 processes the received guidance signals, along with test signals, to detect any faults in the operation of receiver 100. The test signals are injected during the flight of the associated aircraft, including during the landing phase. Further, the wideband feature of front ends 102 and 104 enable receipt of the assigned guidance signal without requiring tuning to a particular guidance signal and enables contemporaneous receipt of the test signal. This enables receiver 100 to simultaneously provide input to the flight control system and also detect faults in the circuitry by processing a known test signal in a real time.

[0015] Wideband front end 102 is coupled to antenna 108. In one embodiment, wideband front end 102 is tuned to receive the localizer (horizontal guidance) channels in the VHF navigation band (e.g., 108-112 MHz). First test signal generator 112 is coupled to inject a first test signal into wideband front end 102. The first test signal is injected while the aircraft is in flight, including during landing. In one embodiment, the first test signal is injected at an edge of the band, e.g., at 108 or 112 MHz. In other embodiments, the test signal is injected at other appropriate frequencies in the bandwidth of wideband front end 102. The output of wideband front end 102 is coupled to A/D converter 116. A/D converter 116 converts the wideband output signal, e.g., the VHF navigation band, into digitized spectrum. The digitized spectrum includes the specific localizer signal assigned to the aircraft for the receiver 100 as well as the test signal from first test signal generator 112.

[0016] Wideband front end 104 is coupled to antenna 110. In one embodiment, wideband front end 104 is tuned to receive the glide slope (vertical guidance) channels in the UHF navigation band (e.g., 328-336 MHz). Second test signal generator 114 is coupled to inject a second test signal into wideband front end 104. The second test signal is injected during the flight including during the landing phase. In one embodiment, the second test signal is injected at an edge of the band, e.g., at 328 or 336 MHz. In other embodiments, the test signal is injected at other appropriate frequencies in the bandwidth of wideband front end 104. The output of wideband front end 104 is coupled to A/D converter 118. A/D converter 118 converts the wideband output signal, e.g., the UHF navigation band, into digitized spectrum. The digitized spectrum includes the specific glide slope signal assigned to the aircraft for the receiver 100 as well as the test signal from second test signal generator 114.

[0017] Figure 1 illustrates one embodiment of wideband front end. For example, wideband front end 102, in one embodiment, includes bandpass filter 124 that is coupled to the output of antenna 108. Bandpass filter is tuned to the appropriate frequency band. In one example, this frequency band is the VHF navigation band. Bandpass filter 124 is coupled to Low Noise Amplifier (LNA) 126. LNA 126 is coupled to mixer 128 that down-converts

the output of LNA 126 to an intermediate frequency using a fixed local oscillator. The output of mixer 128 is provided to bandpass filter 130. The output of bandpass filter 130 is coupled to A/D converter 116. A/D converter 116 digitizes the down-converted frequency band, e.g., the VHF frequency band that has been down-converted to an intermediate frequency. This down-converted, digitized frequency band includes the channels that are used to carry the localizer signal as well as the first test signal. Wideband front end 104 similarly includes serially connected bandpass filter 132, low noise amplifier 134, mixer 136 and bandpass filter 138. These components of wideband front end 104 are tuned to process a second frequency band, such as the UHF navigation band, to provide a down-converted, digitized frequency band that includes the channels that are used to carry the glide slope signal as well as the second test signal.

[0018] Bank of digital down-converters 106 extracts signals from the digitized spectrum output by A/D converters 116 and 118 to be used by the receiver 100 for fault detection and flight control. First, some of the digital down-converters (DDC) are used to generate flight control information and to detect faults in the digital circuitry. DDC 140 and DDC 142 each down-convert a selected channel containing the desired first guidance signal, such as a localizer signal, and reject all other signals present in the digitized spectrum output from A/D converter 116. Further, DDC 144 and DDC 145 each down-convert a selected channel containing the desired second guidance signal, such as a glide slope signal, and reject all other signals present in the digitized output of A/D converter 118. The output of DDC 140 and 144 are used by main processor 120 to generate lateral and vertical guidance for the flight control system. Similar calculations are made by monitor processor 122 based on the outputs of DDC 142 and DDC 145. Monitor processor 122 compares the lateral and vertical guidance output of main processor 120 with its own calculation and declares a fault when the calculations of either lateral or vertical guidance do not match. This fault is communicated from monitor processor 122 to main processor 120. Main processor 120 flags the non-matching lateral or vertical guidance output as invalid.

[0019] Second, bank of digital down-converters 106 also includes DDCs that are tuned to down-convert signals used to identify faults in the analog circuitry. For example, bank of digital down-converters 106 includes DDC 148 and DDC 150. DDC 148 is tuned to down-convert the first test signal and to reject all other signals from the digitized spectrum output from A/D converter 116. Similarly, DDC 150 is tuned to down-convert the second test signal and to reject all other signals from the digitized spectrum output by A/D 118. Monitor processor 122 compares the first and second test signals from DDC 148 and DDC 150 with the expected results from the respective test signals. If the comparisons exceed accuracy limits, monitor processor 122 detects faults in wideband front end 102 and/or wideband front end 104. These faults are

communicated by monitor processor 122 to main processor 120. Main processor 120 flags the guidance signal associated with the faulty wideband front end as invalid.

[0020] Although Figure 1 has been shown with first and second wideband front ends, it is understood that any appropriate number of wideband front ends could be used in a particular embodiment based on the bands used to carry the expected and test signals. For example, a single wideband front end could be used if the expected signal(s) are carried within a bandwidth associated with the wideband front end.

[0021] Figure 2 is a flow chart of one embodiment of a method 200 for detecting faults in an on-board receiver of an ILS according to one embodiment of the present invention. The method uses injected test signals along with redundant digital processing of guidance signals to detect faults in both the analog circuitry and digital circuitry of the receiver.

[0022] At block 202, the method receives signals in one or more navigation bands from an ILS. For example, the method receives signals in VHF and UHF navigation bands that include both glide slope and localizer signals from the ILS. At block 204, the method further injects test signals that are used to test analog circuitry of the receiver for faults. In one embodiment, a test signal is injected in each navigation band while the aircraft is in flight, including during the landing phase. Further, in one embodiment, the test signals are injected at a frequency adjacent to a band that contains an expected signal, e.g., adjacent to a respective navigation band. The signals in the navigation band and the test signals are combined (block 205) and, at block 206, the method converts the received navigation bands to digitized spectrum. The digitized spectrum includes each of the navigation bands along with the injected test signals.

[0023] The method 200 processes the digitized spectrum to detect faults in the analog and digital circuitry of the receiver. For the analog circuitry and mixed signal A/D converters, at block 212, the method digitally down-converts and extracts the test signals from among all the signals present in the digitized spectrum. At block 214, the method monitors the down-converted test signals for failure in the analog circuitry and/or mixed signal A/D converters. For example, the method compares the received test signals with expected values and declares a fault based on the comparison. For the digital circuitry, the method down-converts and extracts the desired, i.e. selected, guidance signals from among all the signals present in the navigation band such as the glide slope and localizer signals, at block 208. The guidance signals are then processed to compute and output the lateral and vertical deviations from the landing path at block 209. The method further monitors (210) the computed lateral and vertical deviations for faults in the digital circuitry. In one embodiment, the down conversion, extraction of the desired guidance signals, and lateral and vertical deviation calculations are performed in parallel using redundant and maybe even dissimilar digital processing cir-

cuitry. Disagreement between the redundant lateral or vertical deviation calculations indicates a fault in the digital circuitry.

[0024] Figure 3 is a perspective diagram of an ILS 300 with real-time detection of faults of on-board receiver 308 according to one embodiment of the present invention. ILS 300 shows transmission of localizer and glide slope signals from ground station antenna 302 and 304, respectively. Aircraft 305 includes on-board receiver 308. This receiver, in one embodiment, is constructed as described above with respect to Figure 1 and functions as described with respect to Figures 1 or 2. On-board receiver 308 has a wideband front end that is coupled to first and second antenna 310 and 312 to receive guidance signals in two navigation bands. For example, antenna 310 receives a localizer signal in the VHF navigation band and antenna 312 receives a glide slope signal in the UHF navigation band. On-board receiver 308 uses these signals, along with test signals injected at the edge of the navigation bands, to provide fault detection for the analog and digital circuitry of on-board receiver 308. The analog and some digital circuitry are tested for faults based on the test signals. Further, the digital circuitry is tested for faults based on the received guidance signals from the navigation bands. The receiver 308 provides real-time fault detection by digitizing each navigation band and then digitally down-converting the test and guidance signals.

[0025] Figure 4 is a block diagram of another embodiment of the present invention. Electronic system 400 includes analog circuitry 402, analog to digital converter (A/D) 404 and digital circuitry 406. Electronic system 400 receives an input signal at analog circuitry 402 and provides an output signal at digital circuitry 406. Analog circuitry 402 also receives a test signal. The test signal is processed by the same circuitry that processes the input signal and is used to detect faults in electronic system 400. Advantageously, electronic system 400 is enabled to test for faults while processing live signals.

[0026] In one embodiment, analog circuitry 402 has a wide bandwidth that accepts a band that includes the input signal. The test signal is injected to analog circuitry 402. In one embodiment, the injected test signal is injected at an edge of the band that contains the input signal.

[0027] In one embodiment, digital circuitry 400 detects faults in electronic system 400. Digital circuitry 406 detects faults in analog circuitry 402, A/D converter 404, and digital circuitry 406 using the injected test signal. Digital circuitry 406 compares the received test signal with an expected test signal and declares a fault based on a difference between the expected signal and the test signal.

[0028] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiments shown. Therefore, it is manifestly intended that this invention be

limited only by the claims.

Claims

1. A receiver (100) for an instrument landing system with real-time fault detection, the receiver comprising:
 - a test signal generator (112);
 - an antenna (108);
 - a wideband front end (108), having an input coupled to the antenna and the test signal generator, wherein the test signal generator injects a test signal at an edge of a selected RF band that contains an expected guidance signal, the test signal used to identify faults in the instrument landing system;
 - an analog to digital, A/D, converter (116) coupled to an output of the wideband front end that generates digitized spectrum, the digitized spectrum including the injected test signal and the selected RF band, including the expected guidance signal;
 - a bank of digital down-converters (106), coupled to the output of the A/D converter;
 - a main processor (120) selectively coupled to the bank of digital down-converters;
 - a monitor processor (122) selectively coupled to the bank of digital down-converters;
 - wherein the bank of digital down-converters selectively provide the test signal and the expected guidance signal from the digitized spectrum to the main and monitor processors to provide lateral and vertical guidance to a flight control system, and wherein the monitor processor detects faults in the analog and digital circuitry of the receiver.
2. The receiver of claim 1, and further comprising a second wideband front end (104) that is coupled to a second antenna (110) and a second test signal generator (114), wherein the second test signal generator injects a second test signal at an edge of a selected RF band that contains a second guidance signal used in the instrument landing system.
3. The receiver of claim 2, wherein:
 - the selected RF band of the wideband front end comprises a VHF band that includes a localizer signal; and
 - the second selected RF band of the second wideband front end comprises a UHF band that includes a glide slope signal.
4. The receiver of claim 3, wherein the monitor processor uses the injected test signals to detect faults in

the analog circuitry and the monitor and main processors use the localizer signal and the glide slope signal to detect faults in the digital circuitry.

5. The receiver of claim 1, wherein:

the antenna comprises first and second antennas (108, 110);

the wideband front end comprises:

a first wideband front end (102) for a first band, having an input coupled to the first antenna, wherein the test signal generator injects a first test signal at an edge of the first band;

a second wideband front end (104) for a second band, having an input coupled to the second antenna, wherein the test signal generator injects a second test signal at an edge of the second band;

the A/D converter comprises:

a first analog to digital (A/D) converter (116) coupled to an output of the first wideband front end;

a second analog to digital (A/D) converter (118) coupled to an output of the second wideband front end;

the bank of digital down-converters are coupled to the outputs of the first and second A/D converters;

wherein the bank of digital down-converters provide the first and second test signals to the monitor processor to continuously monitor for faults in the first and second wideband front ends;

wherein the bank of digital down-converters also provide a selected channel from the first wideband front end to the main processor and to the monitor processor and provide a selected channel from the second wideband front end to the main processor and to the monitor processor; and

wherein the main processor and the monitor processor perform parallel, redundant computations of the lateral and vertical deviation and compare the computations to detect any faults in the bank of digital down-converters, the main processor and the monitor processor.

6. The receiver of claim 5, wherein the bank of digital down-converters includes:

a first digital down-converter (140), coupled between the first A/D converter and the main processor, the first digital down-converter down converting a selected localizer channel in the first

band assigned to the receiver;
 a second digital down-converter (144), coupled between the second A/D converter and the main processor, the second digital down-converter converting a selected glide slope channel in the second band assigned to the receiver;
 a third digital down-converter (142), coupled between the first A/D converter and the monitor processor, the third digital down-converter down converting the selected localizer channel in the first band assigned to the receiver; and
 a fourth digital down-converter (145), coupled between the second A/D converter and the monitor processor, the fourth digital down-converter converting the selected glide slope channel in the second band assigned to the receiver.

7. A method for real-time fault detection in a receiver of an instrument landing system, the method comprising:

receiving a band from a transmitter of the instrument landing system, the band including an expected signal;

injecting a test signal at a frequency adjacent to the band that contains the expected signal;

converting the test signal and the band that contains the expected signal to a digitized spectrum, the digitized spectrum including the test signal and the band that contains the expected signal;

selectively down-converting the expected signal and the test signal from the digitized spectrum; monitoring the down-converted test signal to identify faults in analog and mixed signal circuitry of the receiver;

computing vertical and lateral deviation based on the down-converted expected signals; and monitoring the computed vertical and lateral deviations;

identifying faults in digital circuitry of the receiver; and

providing lateral and vertical guidance to an aircraft system based on the down-converted expected signal.

8. The method of claim 7, wherein receiving the guidance signal from a transmitter of an instrument landing system comprises receiving localizer and glide slope signals.

9. The method of claim 8, wherein injecting the test signal comprises injecting a first test signal adjacent to a VHF band used for the localizer signal and injecting a second test signal adjacent to a UHF band used for the glide slope signal.

10. The method of claim 7, wherein computing vertical and lateral deviations comprises separately comput-

ing vertical and lateral deviations in parallel, redundant paths.

Patentansprüche

1. Empfänger (100) für ein Instrumentenlandesystem mit Echtzeitfehlererkennung, wobei der Empfänger umfasst:

einen Testsignalgenerator (112);
 eine Antenne (108);
 ein Breitband-Frontend (108) mit einem Eingang, der mit der Antenne und dem Testsignalgenerator gekoppelt ist, wobei der Testsignalgenerator ein Testsignal an einer Flanke eines ausgewählten HF-Bandes einspeist, das ein erwartetes Führungssignal enthält, wobei das Testsignal verwendet wird, um Fehler im Instrumentenlandesystem zu identifizieren;
 einen Analog-Digital-A/D-Wandler (116), der mit einem Ausgang des Breitband-Frontends gekoppelt ist, das ein digitalisiertes Spektrum erzeugt, wobei das digitalisierte Spektrum das eingespeiste Testsignal und das ausgewählte HF-Band einschließlich des erwarteten Führungssignals enthält;
 eine Bank von digitalen Abwärtswandlern (106), die mit dem Ausgang des A/D-Wandlers gekoppelt sind;
 einen Hauptprozessor (120), der selektiv mit der Bank von digitalen Abwärtswandlern gekoppelt ist;
 einen Überwachungsprozessor (122), der selektiv mit der Bank von digitalen Abwärtswandlern gekoppelt ist;
 wobei die Bank von digitalen Abwärtswandlern selektiv das Testsignal und das erwartete Führungssignal aus dem digitalisierten Spektrum an die Haupt- und Überwachungsprozessoren liefert, um eine laterale und vertikale Führung für ein Flugsteuerungssystem bereitzustellen, und wobei der Überwachungsprozessor Fehler in der analogen und digitalen Schaltungsanordnung des Empfängers erkennt.

2. Empfänger nach Anspruch 1 und ferner umfassend ein zweites Breitband-Frontend (104), das mit einer zweiten Antenne (110) und einem zweiten Testsignalgenerator (114) gekoppelt ist, wobei der zweite Testsignalgenerator ein zweites Testsignal an einer Flanke eines ausgewählten HF-Bandes einspeist, das ein zweites Führungssignal enthält, das in dem Instrumentenlandesystem verwendet wird.

3. Empfänger nach Anspruch 2, wobei:

das ausgewählte HF-Band des Breitband-Fron-

tends ein UKW-Band umfasst, das ein Landekursendersignal enthält; und
 das zweite ausgewählte HF-Band des zweiten Breitband-Frontends ein UHF-Band umfasst, das ein Gleitwegsendersignal enthält.

4. Empfänger nach Anspruch 3, wobei der Überwachungsprozessor die eingespeisten Testsignale verwendet, um Fehler in der analogen Schaltung zu erfassen, und der Überwachungs- und der Hauptprozessor das Landekursendersignal und das Gleitwegsendersignal verwenden, um Fehler in der digitalen Schaltung zu erfassen.

5. Empfänger nach Anspruch 1, wobei:

die Antenne eine erste und eine zweite Antenne (108, 110) umfasst;
 das Breitband-Frontend umfasst:

ein erstes Breitband-Frontend (102) für ein erstes Band, mit einem Eingang, der mit der ersten Antenne gekoppelt ist, wobei der Testsignalgenerator ein erstes Testsignal an einer Flanke des ersten Bandes einspeist;
 ein zweites Breitband-Frontend (104) für ein zweites Band, mit einem Eingang, der mit der zweiten Antenne gekoppelt ist, wobei der Testsignalgenerator ein zweites Testsignal an einer Flanke des zweiten Bandes einspeist;

der A/D-Wandler umfasst:

einen ersten Analog-Digital-Wandler (A/D) (116), der mit einem Ausgang des ersten Breitband-Frontends gekoppelt ist;
 einen zweiten Analog-Digital-Wandler (A/D) (118), der mit einem Ausgang des zweiten Breitband-Frontends verbunden ist;
 die Bank von digitalen Abwärtswandlern mit den Ausgängen des ersten und des zweiten A/D-Wandlers gekoppelt ist;
 wobei die Bank von digitalen Abwärtswandlern das erste und das zweite Testsignal an den Überwachungsprozessor liefert, um kontinuierlich auf Fehler im ersten und zweiten Breitband-Frontend zu überwachen;
 wobei die Bank von digitalen Abwärtswandlern auch einen ausgewählten Kanal vom ersten Breitband-Frontend zum Hauptprozessor und zum Überwachungsprozessor bereitstellt und
 einen ausgewählten Kanal vom zweiten Breitband-Frontend zum Hauptprozessor und zum Überwachungsprozessor bereit-

- stellt; und
wobei der Hauptprozessor und der Überwachungsprozessor parallele, redundante Berechnungen der lateralen und vertikalen Abweichung durchführen und die Berechnungen vergleichen, um etwaige Fehler in der Bank von digitalen Abwärtswandlern, des Hauptprozessors und des Überwachungsprozessors zu erkennen.
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6. Empfänger nach Anspruch 5, wobei die Bank von digitalen Abwärtswandlern enthält:
- einen ersten digitalen Abwärtswandler (140), der zwischen dem ersten A/D-Wandler und dem Hauptprozessor gekoppelt ist, wobei der erste digitale Abwärtswandler einen ausgewählten Landekursenderkanal in dem ersten Band, das dem Empfänger zugewiesen ist, abwärtswandelt;
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- einen zweiten digitalen Abwärtssumwandler (144), der zwischen den zweiten A/D-Wandler und den Hauptprozessor gekoppelt ist, wobei der zweite digitale Abwärtssumwandler einen ausgewählten Gleitwegsenderkanal im zweiten Band, das dem Empfänger zugewiesen ist, umwandelt;
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- einen dritten digitalen Abwärtswandler (142), der zwischen dem ersten A/D-Wandler und dem Überwachungsprozessor gekoppelt ist, wobei der dritte digitale Abwärtswandler den ausgewählten Landekursenderkanal in dem ersten Band, das dem Empfänger zugewiesen ist, abwärtswandelt; und
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- einen vierten digitalen Abwärtswandler (145), der zwischen dem zweiten A/D-Wandler und dem Überwachungsprozessor gekoppelt ist, wobei der vierte digitale Abwärtswandler den ausgewählten Gleitwegsenderkanal in dem zweiten Band, das dem Empfänger zugewiesen ist, umwandelt.
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7. Verfahren zur Echtzeit-Fehlererkennung in einem Empfänger eines Instrumentenlandesystems, wobei das Verfahren umfasst:
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- Empfangen eines Bandes von einem Sender des Instrumentenlandesystems, wobei das Band ein erwartetes Signal enthält;
- 45
- Einspeisen eines Testsignals mit einer Frequenz neben dem Band, das das erwartete Signal enthält;
- 50
- Umwandeln des Testsignals und des Bandes, das das erwartete Signal enthält, in ein digitalisiertes Spektrum, wobei das digitalisierte Spektrum das Testsignal enthält und das Band, das das erwartete Signal enthält;
- 55
- selektives Abwärtssumwandeln des erwarteten Signals und des Testsignals aus dem digitalisierten Spektrum;
- Überwachen des abwärtsgewandelten Testsignals, um Fehler in der analogen und gemischten Signalschaltung des Empfängers zu identifizieren;
- Berechnen der vertikalen und lateralen Abweichung auf der Grundlage der abwärtsgewandelten erwarteten Signale; und
- Überwachen der berechneten vertikalen und lateralen Abweichungen;
- Identifizieren von Fehlern in der digitalen Schaltung des Empfängers; und
- Bereitstellen einer lateralen und vertikalen Führung für ein Flugzeugsystem auf der Grundlage des abwärtsgewandelten erwarteten Signals.
8. Verfahren nach Anspruch 7, wobei das Empfangen des Führungssignals von einem Sender eines Instrumentenlandesystems das Empfangen von Landekursender- und Gleitwegsendersignalen umfasst.
9. Verfahren nach Anspruch 8, wobei das Einspeisen des Testsignals das Einspeisen eines ersten Testsignals neben einem UKW-Band, das für das Landekursendersignal verwendet wird, und das Einspeisen eines zweiten Testsignals neben einem UHF-Band, das für das Gleitwegsendersignal verwendet wird, umfasst.
10. Verfahren nach Anspruch 7, wobei das Berechnen vertikaler und lateraler Abweichungen das separate Berechnen vertikaler und lateraler Abweichungen in parallelen, redundanten Pfaden umfasst.

Revendications

1. Récepteur (100) pour un système d'atterrissage aux instruments avec détection des pannes en temps réel, le récepteur comprenant :
- un générateur de signal de test (112) ;
- une antenne (108) ;
- une extrémité avant à large bande (108), ayant une entrée couplée à l'antenne et au générateur de signal de test, dans laquelle le générateur de signal de test injecte un signal de test à un bord d'une bande RF sélectionnée qui contient un signal de guidage attendu, le signal de test utilisé pour identifier des pannes dans le système d'atterrissage aux instruments ;
- un convertisseur analogique/numérique A/N (116) couplé à une sortie de l'extrémité avant à large bande qui génère un spectre numérisé, le spectre numérisé comprenant le signal de test injecté et la bande RF sélectionnée, y compris

- le signal de guidage attendu ;
 une batterie de convertisseurs abaisseurs numériques (106), couplée à la sortie du convertisseur A/N ;
 un processeur principal (120) couplé sélectivement à la banque de convertisseurs abaisseurs numériques ;
 un processeur de contrôle (122) couplé sélectivement à la banque de convertisseurs abaisseurs numériques ;
 dans lequel la banque de convertisseurs abaisseurs numériques fournit sélectivement le signal de test et le signal de guidage attendu du spectre numérisé aux processeurs principal et de contrôle pour fournir un guidage latéral et vertical à un système de commande de vol, et dans lequel le processeur de contrôle détecte des pannes des circuits analogiques et numériques du récepteur.
2. Récepteur selon la revendication 1, et comprenant en outre une deuxième extrémité avant à large bande (104) qui est couplée à une deuxième antenne (110) et à un deuxième générateur de signal de test (114), dans lequel le deuxième générateur de signal de test injecte un deuxième signal de test à un bord d'une bande RF sélectionnée qui contient un deuxième signal de guidage utilisé dans le système d'atterrissage aux instruments.
3. Récepteur selon la revendication 2, dans lequel :
- la bande RF sélectionnée de l'extrémité avant à large bande comprend une bande VHF qui comprend un signal de localisation ; et
 la deuxième bande RF sélectionnée de la deuxième extrémité avant à large bande comprend une bande UHF qui comprend un signal de pente de descente.
4. Récepteur selon la revendication 3, dans lequel le processeur de contrôle utilise les signaux de test injectés pour détecter des pannes dans les circuits analogiques et les processeurs de contrôle et principal utilisent le signal de localisation et le signal de pente de descente pour détecter des pannes dans les circuits numériques.
5. Récepteur selon la revendication 1, dans lequel :
- l'antenne comprend des première et deuxième antennes (108, 110) ;
 l'extrémité avant à large bande comprend :
- une première extrémité avant à large bande (102) pour une première bande, ayant une entrée couplée à la première antenne, dans lequel le générateur de signal de test injecte
- un premier signal de test à un bord de la première bande ;
 une deuxième extrémité avant à large bande (104) pour une deuxième bande, ayant une entrée couplée à la deuxième antenne, dans lequel le générateur de signal de test injecte un deuxième signal de test à un bord de la deuxième bande ;
- le convertisseur A/N comprend :
- un premier convertisseur analogique-numérique (A/N) (116) couplé à une sortie de la première extrémité avant à large bande ;
 un deuxième convertisseur analogique-numérique (A/N) (118) couplé à une sortie de la deuxième extrémité avant à large bande ;
 la banque de convertisseurs abaisseurs numériques est couplée aux sorties des premier et deuxième convertisseurs A/N ;
 dans lequel la banque de convertisseurs abaisseurs numériques fournit les premier et deuxième signaux de test au processeur de contrôle pour surveiller en continu des pannes dans les première et deuxième extrémités avant à large bande ;
 dans lequel la banque de convertisseurs abaisseurs numériques fournit également un canal sélectionné de la première extrémité avant à large bande au processeur principal et au processeur de contrôle et fournit un canal sélectionné de la deuxième extrémité avant à large bande au processeur principal et au processeur de contrôle ;
 et
 dans lequel le processeur principal et le processeur de contrôle effectuent des calculs redondants parallèles de l'écart latéral et vertical et comparent les calculs pour détecter toute panne dans la banque de convertisseurs abaisseurs numériques, le processeur principal et le processeur de contrôle.
6. Récepteur selon la revendication 5, dans lequel la banque de convertisseurs abaisseurs numériques comprend :
- un premier convertisseur abaisseur numérique (140), couplé entre le premier convertisseur A/N et le processeur principal, le premier convertisseur abaisseur numérique convertissant un canal de localisation sélectionné dans la première bande affectée au récepteur ;
 un deuxième convertisseur abaisseur numérique (144), couplé entre le deuxième convertisseur A/N et le processeur principal, le deuxième convertisseur abaisseur numérique convertis-

- sant un canal de pente de descente sélectionné dans la deuxième bande affectée au récepteur ; un troisième convertisseur abaisseur numérique (142), couplé entre le premier convertisseur A/N et le processeur de contrôle, le troisième convertisseur abaisseur numérique convertissant le canal de localisation sélectionné dans la première bande affectée au récepteur ; et un quatrième convertisseur abaisseur numérique (145), couplé entre le deuxième convertisseur A/N et le processeur de contrôle, le quatrième convertisseur abaisseur numérique convertissant le canal de pente de descente sélectionné dans la deuxième bande affectée au récepteur.
7. Procédé de détection des pannes en temps réel dans un récepteur d'un système d'atterrissage aux instruments, le procédé comprenant :
- la réception d'une bande d'un émetteur du système d'atterrissage aux instruments, la bande comprenant un signal attendu ;
l'injection d'un signal de test à une fréquence adjacente à la bande qui contient le signal attendu ;
la conversion du signal de test et de la bande qui contient le signal attendu en un spectre numérisé, le spectre numérisé comprenant le signal de test et la bande qui contient le signal attendu ;
la conversion sélective à la baisse du signal attendu et du signal de test du spectre numérisé ;
la surveillance du signal de test converti à la baisse pour identifier des pannes dans des circuits de signaux analogiques et mixtes du récepteur ;
le calcul d'un écart vertical et latéral sur la base des signaux attendus convertis à la baisse ; et
la surveillance des écarts verticaux et latéraux calculés ;
l'identification de pannes dans des circuits numériques du récepteur ; et
la fourniture d'un guidage latéral et vertical à un système d'aéronef sur la base du signal attendu converti à la baisse.
8. Procédé selon la revendication 7, dans lequel la réception du signal de guidage d'un émetteur d'un système d'atterrissage aux instruments comprend la réception de signaux de localisation et de pente de descente.
9. Procédé selon la revendication 8, dans lequel l'injection du signal de test comprend l'injection d'un premier signal de test adjacent à une bande VHF utilisée pour le signal de localisation et l'injection d'un deuxième signal de test adjacent à une bande UHF
- utilisée pour le signal de pente de descente.
10. Procédé selon la revendication 7, dans lequel le calcul d'écarts verticaux et latéraux comprend le calcul séparé d'écarts verticaux et latéraux dans des chemins redondants parallèles.

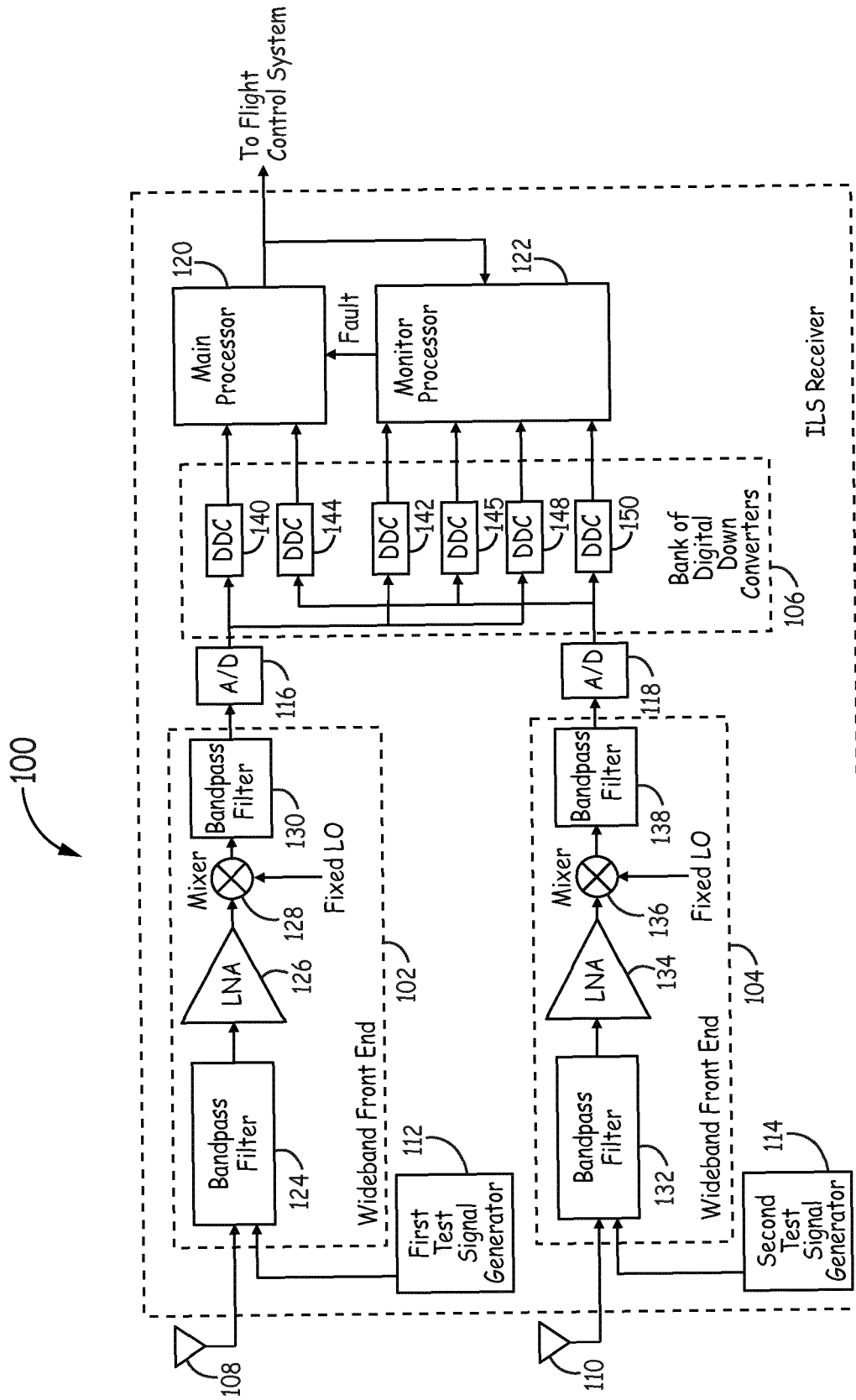


FIG. 1

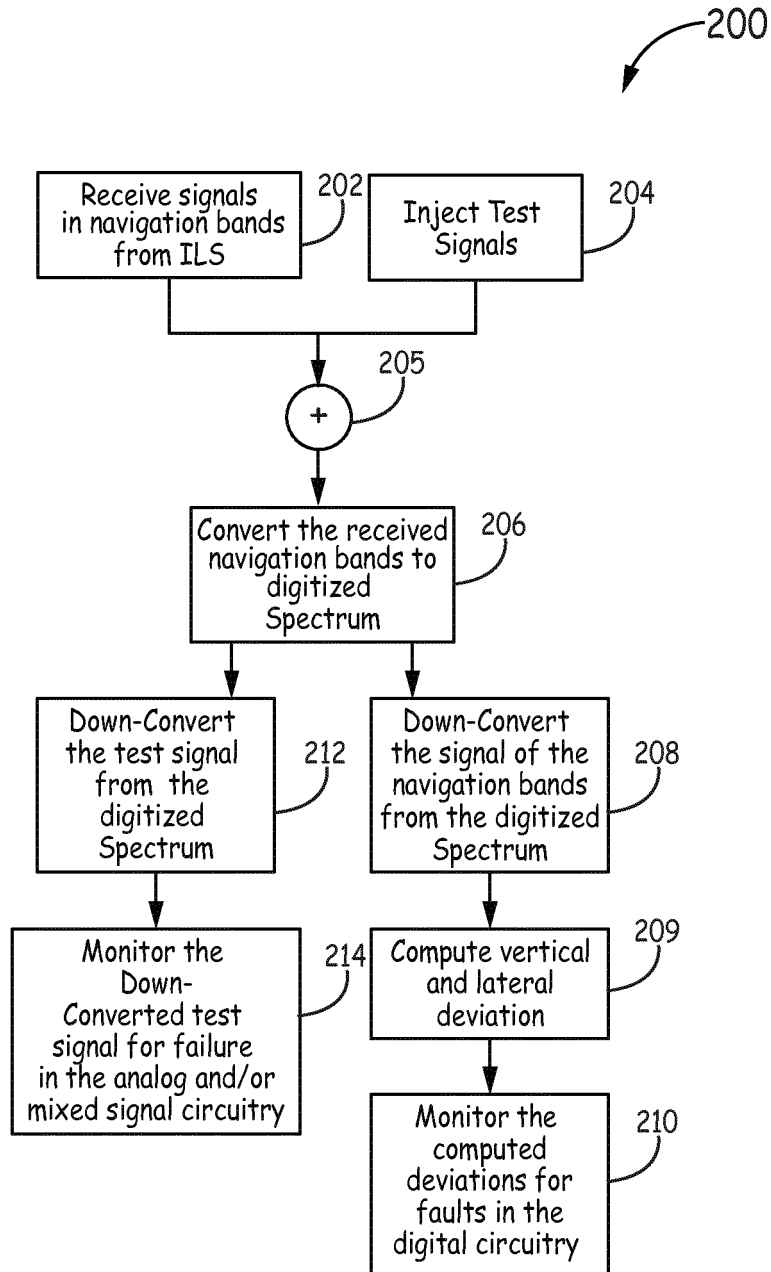


FIG. 2

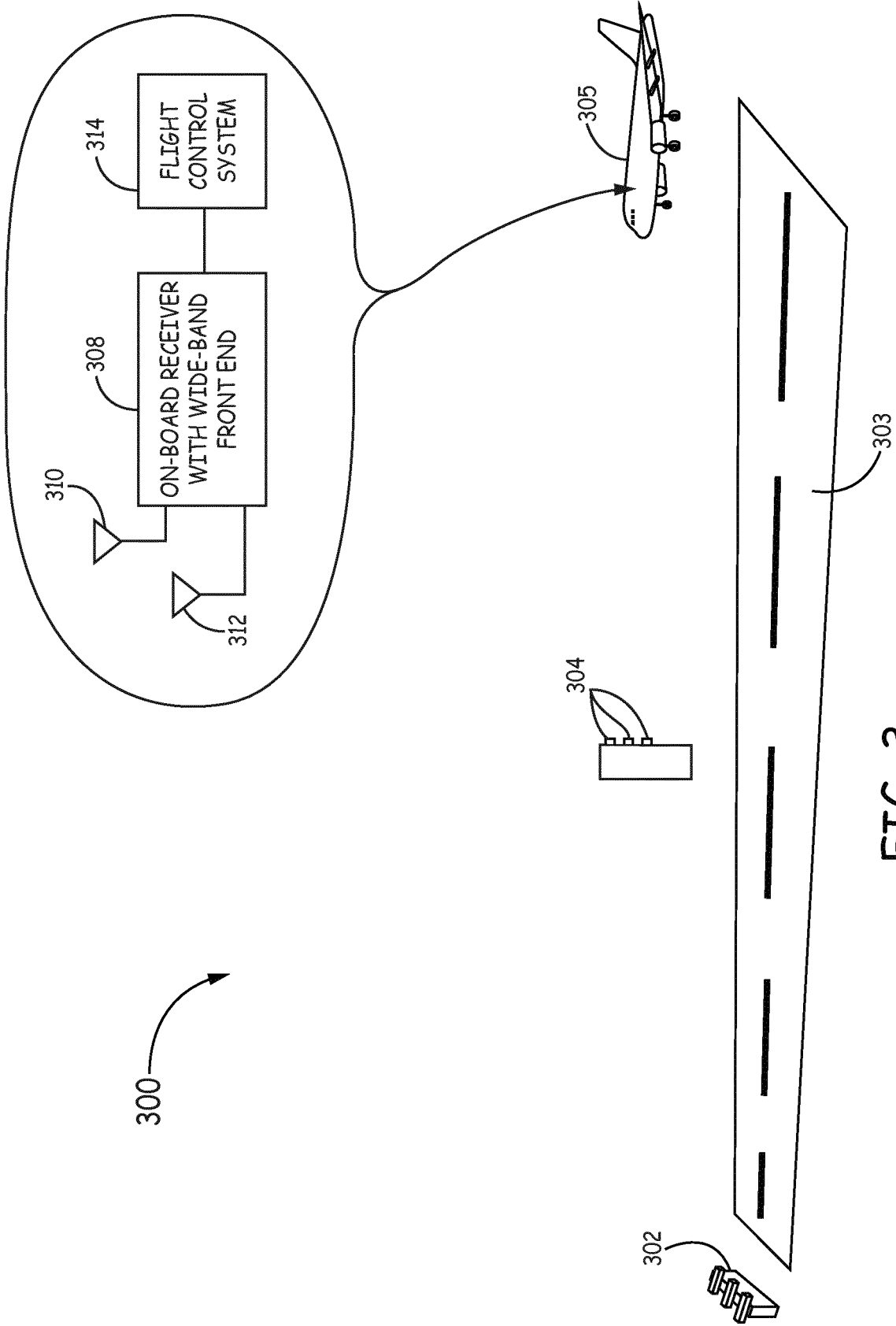


FIG. 3

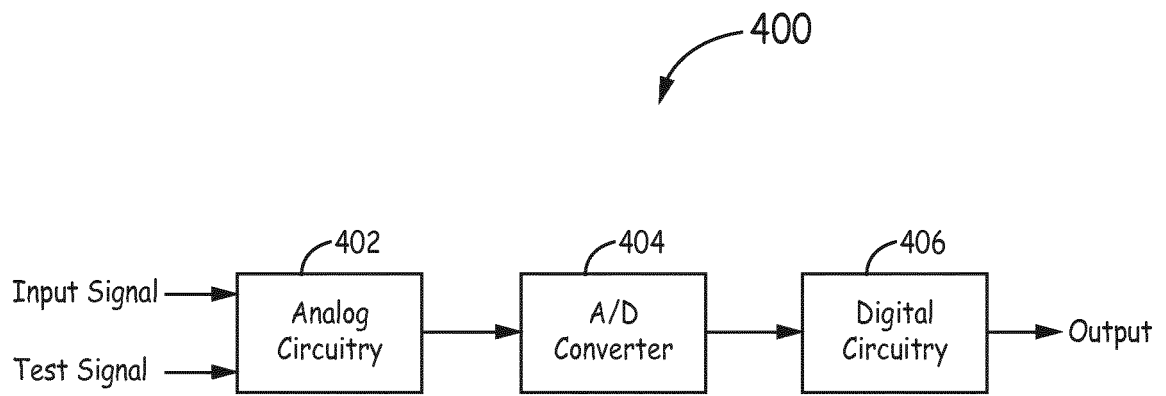


FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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